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CITY OF KIRKLAND

TOTEM LAKE CONNECTOR

TYPE, SIZE AND LOCATION STUDY

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APPENDICES

1 Executive Summary

The Totem Lake Connector is a grade separated crossing of NE 124th St and 124th Ave NE / Totem Lake Boulevard dedicated to non-vehicular travel of pedestrians and cyclists. This bridge crossing will provide quick, safe passage across the busiest intersection in the City of Kirkland. The City desires a structurally dramatic bridge that will become a gateway for Totem Lake.

This report summarizes the data gathering, studies, and concept design undertaken during schematic design. Four alternatives are developed and described herein. An Evaluation Criteria was established for assessing the preferred alternative and the Skipping Stone concept is recommended as the option to take forward to Final Design.

1.1 Purpose of Report

This report documents the preliminary design efforts associated with the bridge Type, Size, and Location (TS&L) study. In the body of the document, the details of data gathering and the design process are explained, with the Appendices collating the various reports and studies associated with discipline investigations undertaken to date.

Building on the work of previous reports and the CKC Master Plan, this report describes the design criteria, site conditions/constraints, presents the design process, alternatives studied, comparable cost estimates between alternatives, constructability concerns, the evaluation matrix used to compare the alternatives, and provides a recommended alternative to carry forward to 30% design.

1.2 Project Description

The Totem Lake Connector (TLC) is a non-motorized bridge that will connect the CKC spanning the intersection of NE 124th St and 124th Ave NE / Totem Lake Blvd. The passage of the Cross Kirkland Corridor (CKC) trail over this busy intersection is a powerful symbol of the prioritization of active transportation in the City. Totem Lake is designated as one of several Regional Growth Centers in the Puget Sound Region, and therefore carries increasing importance as a center for retail, residential, and commercial activity.

The preferred alignment of the TLC is shown in Figure 1 below. The bridge will begin on the south end of the site with a retained earth approach ramp, shifting the user pathway slightly to the west of the interim trail. The bridge structure will pass over NE 124th Street onto supports located in the traffic island between NE 124th St and Totem Lake Blvd. The bridge will then pass over Totem Lake Blvd and land on supports just north of Totem Lake Blvd. The bridge will then descend around the loop ramp to eventually join back with the interim CKC trail on the north side of the intersection.

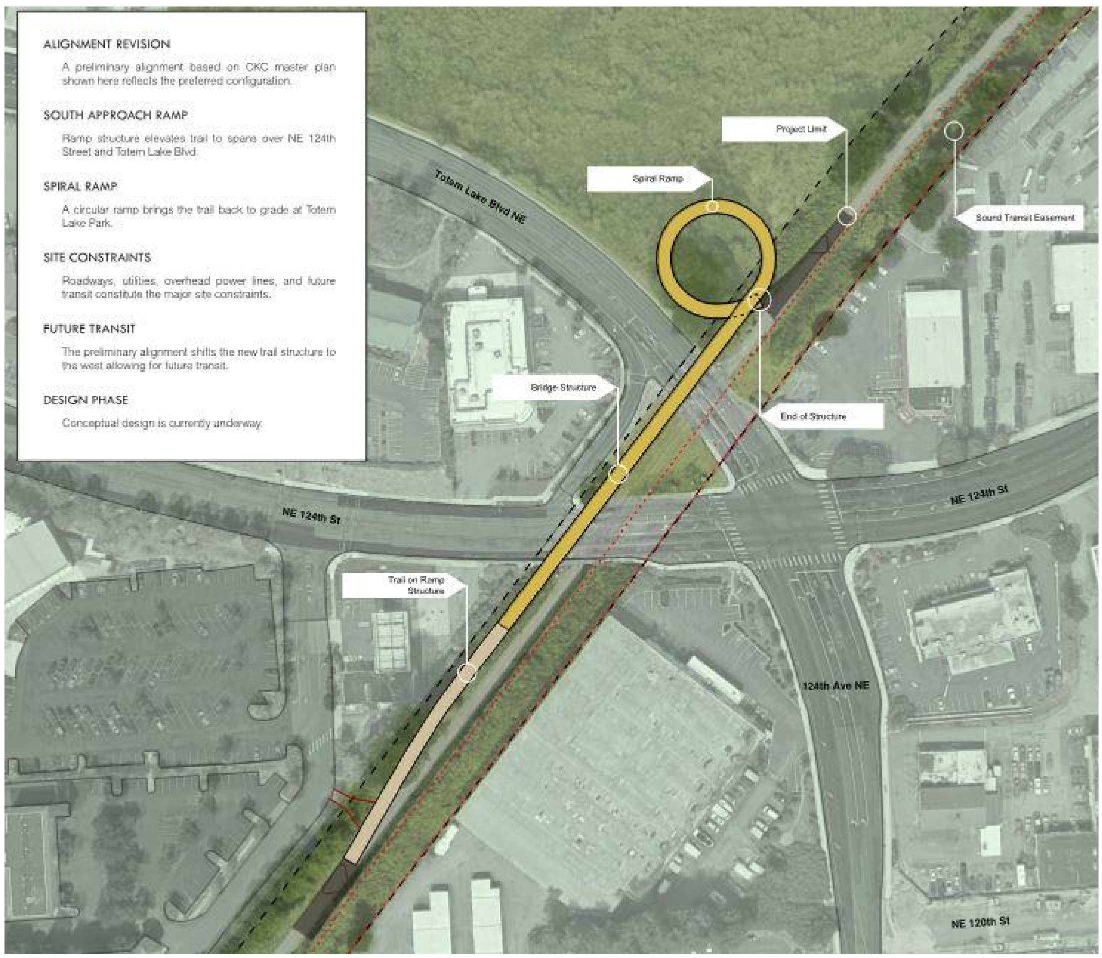

Figure 1: Project Site Layout and Bridge Alignment

1.3 Reference Reports

Development of the Totem Lake Connector was based on the following reports and guidelines. Several of the reports listed below include references to previous work regarding the bridge site:

- Totem Lake Park Master Plan, 2013
- City of Kirkland Design Guidelines for Totem Lake Neighborhood, 2006
- City of Kirkland Design Guidelines for Pedestrian-Oriented Business Districts, 2012
- Cross Kirkland Corridor Master Plan, 2014
- City of Kirkland Comprehensive Plan – Totem Lake Neighborhood, 2011

1.4 Background and History

The Totem Lake Connector is part of a larger vision for the CKC and was conceived during development of the CKC Master Plan. The Master Plan identifies a corridor-wide approach to developing the Kirkland-owned 5.7 miles of the larger (40+ mile) Eastside Rail Corridor (ERC). Corridor development is to include a shared-use trail within the city limits, connecting with future ERC improvements. The TLC will also support elements of the Totem Lake Park Master Plan, developed by the Kirkland Parks Department. The Totem Lake Park Master Plan as well as the CKC Master Plan envision a crossing at this intersection to connect the CKC with the rest of the regional trail network (shown in Figure 2).

Totem Lake is a designated Regional Growth Center within the Puget Sound Region. The Totem Lake Master Plan envisions growth of the urban center, to prioritize pedestrians and cyclists, and to encourage active transportation between community events, residential, retail, and commercial. The connectivity provided by the TLC is a key piece of the redevelopment vision to make this an attractive place to live and work, while accommodating regional commuters, and attracting visitors.

Figure 2: Regional Trail Network

2 Bridge Design Criteria

The bridge design criteria are described in detail in the Basis of Design document in Appendix C, which covers:

- Design Codes
- Materials
- Bridge Geometry
- Design Loads
- Deflection Criteria
- Vibration Criteria
- Foundation Considerations
- Analysis

Fire access is not required on the bridge. The City has stated they will respond by accessing the bridge on foot to respond to emergencies, the same way they do on the rest of the CKC Trail.

3 Project Goals and Objectives

The Totem Lake Connector will seek to improve pedestrian traffic flow and access, minimize environmental impacts, create a "gateway" to the Totem Lake area and enhance the character of the area, while also being responsive to ongoing current and future development. In developing bridge alternatives, the following City of Kirkland project goals and objectives were considered/implemented:

- Fulfill the Vision - Distinguish the CKC as a unique cultural and recreational destination for the community and region. Provide an experience beyond that of a typical regional trail. Design a structure that stands in harmony with its surroundings and responds to the various constraints and features of the site.

- Support Economic Development - Utilize the corridor's development to catalyze economic growth, encouraging residential and commercial development that can charge the corridor and city with energy and vitality.

- Connect to Regional Trails - Connecting to new and existing trail facilities will make the CKC available to more users and regional destinations. A convenient, direct link between the currently disconnected CKC Trail segments will greatly increase the functionality of the trail and will attract users.

- Non-Motorized Transportation Artery - The CKC will connect with significant growth and density high-use areas with unimpeded travel. Ensuring connections are made with the CKC and key streets, schools, parks, commercial land, and transit will maximize the public benefit.

- Safety - The Totem Lake Connector project will significantly improve safety by providing CKC users with a grade-separated crossing of 124th Avenue NE and NE 124th Street. Crime Prevention through Environmental Design (CPTED) will be implemented by providing clear sightlines throughout the project.

- Create a Destination - The CKC and TLC are envisioned to become destinations. This linear 'park', with the future redevelopment of Totem Lake Park, provides Kirkland residents and visitors with superb recreational opportunities and an enjoyable environment to travel within and between places.

- Ease of Construction/Fabrication - Minimizing traffic disruption at the busiest intersection in Kirkland.

- Minimize Environmental Impacts – Limit impacts to nearby wetlands and natural site features.

4 Project Constraints

The project site has several constraints that have been considered and accounted for in this TS&L study. Included in these constraints are the CKC right-of-way, high traffic roadways (NE 124th St. and Totem Lake Blvd), light controlled intersections, roadway stopping sight distances, storm sewer, sanitary sewer force-mains, power transmission lines (existing and proposed), drainage ditches, wetlands/environmental setbacks, and future NE 120th St roadway extension.

4.1 Utilities

Utilities in the project vicinity include overhead power lines, cable and underground phone lines, and several types of sewer lines. The utilities present have the following owners/stakeholders:

- Sewer and Stormwater – North Shore Utility District, King County Water Treatment Division (along corridor), City of Kirkland (COK) Stormwater sewer
- Water and Irrigation – City of Kirkland (COK)
- Power Lines – Seattle City Light, Puget Sound Energy
- Fiber optic Line – Zayo Group

Through coordination with each of the utility owners listed above, an understanding of the utilities present on the site has been established, along with the appropriate setbacks associated with each. Utility locations are included in the overall survey base map produced as part of the field survey (see Figure 3). The bridge alternatives attempt to avoid impacts with underground and overhead utilities from the foundations and superstructure support system. Construction activities have been considered for each alternative as well.

The bridge structure will be set back from overhead powerlines and structures using appropriate clearances. These clearances have been calculated for PSE lines and provided by SCL for the respective lines passing through the site. This information and analysis is included in Appendix D.

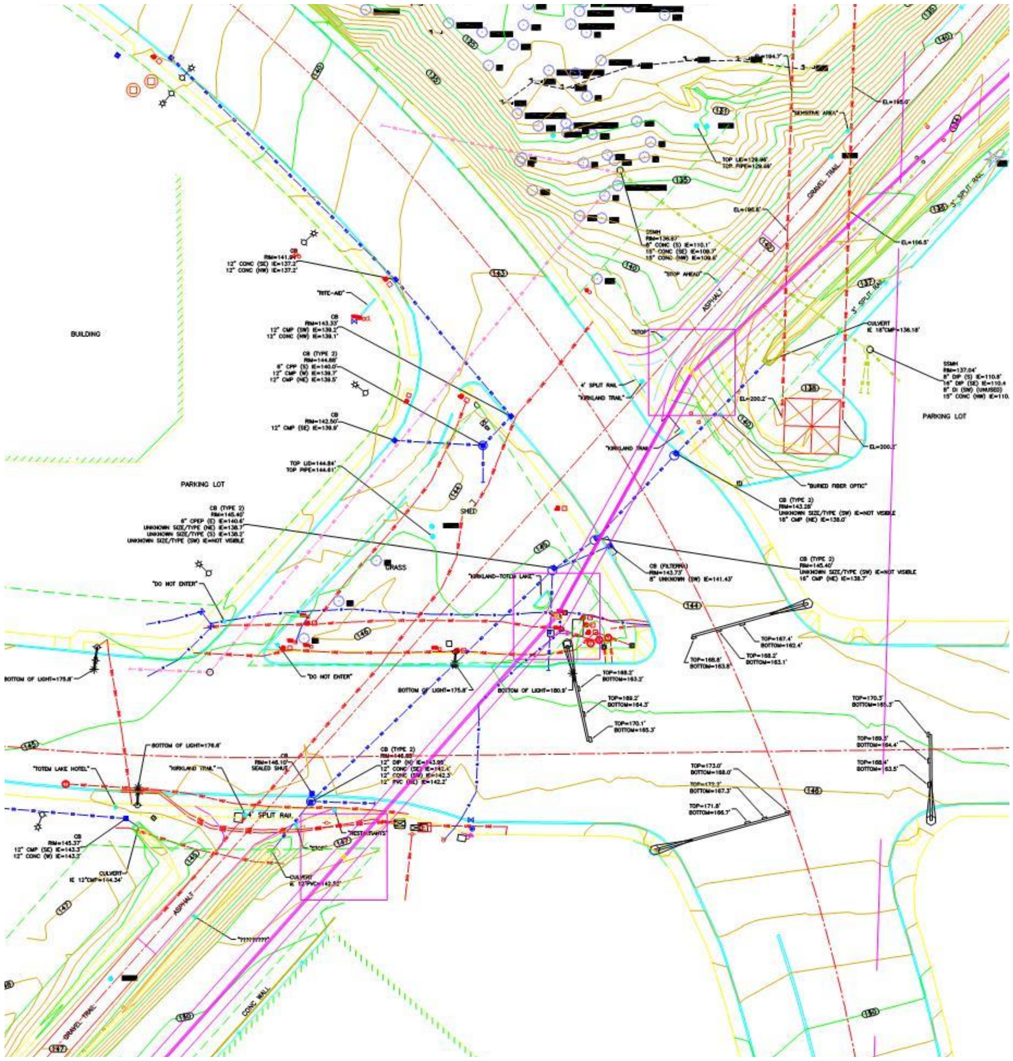

Figure 3: Totem Lake Utilities

In addition to the investigations noted above, the following utility assessments were undertaken:

- One Call was notified,
- APS completed utility locates,
- Ground Penetrating Radar (GPR) scanning was conducted at three of the geotechnical boring sites, and

- Trench excavation was made using a vacuum truck (up to 5 feet deep or to very dense native soils) across the proposed trail alignment within the triangular property to identify if an unknown fiber optic line or any other utilities might exist.

4.2 Wetlands/Permitting

Wetland Delineation, Critical Areas Report, Tree Survey, Area of Potential Effects (APE), Cultural Resources Survey (CRS), and Hazardous Material Study have been completed for the project and are included in the appendices.

4.3 Traffic Impacts

Limited lane closures are anticipated for each of the four alternatives during construction. Span-by-span construction would likely be used for two of the alternatives, where the full span would be placed with a single or multiple night closure. The other options use cantilevered deck construction that have focused impacts on travel lanes without requiring full closure of the roadway during construction.

The trail is expected to be closed for the duration of construction for the sections of trail immediately south and north of the bridge site. The trail detour will be signed in coordination with the City of Kirkland for all options.

4.4 Constructability

Each of the bridge alternatives gives due consideration to ease of fabrication and constructability. Although considered only a 10% level of design, the concepts have been conceived to a much higher level. This provides insights into the means of construction and what impacts it will have on traffic, staging / lay-down areas, and site access.

4.5 Future Transit

Sound Transit has an easement along the eastern 40' of the CKC right-of-way. The TLC preserves this corridor and occupies space in the western portion of the right-of-way.

4.6 Geotechnical

Geotechnical exploration was completed during January and February of 2017. The purpose of the exploration program is to evaluate subsurface soil and groundwater conditions along the project alignment as a basis for developing preliminary geotechnical recommendations during predesign and 30 percent design development. Further investigation will likely be needed prior to final design and construction.

A total of seven borings were drilled along the project alignment, using subcontracted truck- and track-mounted drilling equipment. The borings are typically 8 inches in diameter, and were drilled in two groups as follows:

- Three borings (Borings 1 through 3) were drilled within the adjacent Totem Lake park area where the spiral ramp will be located. These borings were drilled with a track-mounted rig to boring depth around 70 feet. A piezometer was installed in one of the park area borings for the purpose of long-term groundwater level measurements.

- Four borings (Borings 4, 5, 6 and 7) were drilled along the west side of the existing trail alignment with a track-mounted rig. These borings were drilled to depths ranging from 20 to 65 feet. A piezometer was installed in boring B-4.

See Appendix D for the borehole log information.

4.7 Drainage

Drainage ditches that run along either side of the CKC south of NE 124th Street are potentially considered jurisdictional by the Army Corps of Engineers (USACE). A determination on this issue will guide the project moving forward.

The City currently has two projects that are directly impacted by these ditches and their designation by the Army Corps of Engineers: the TLC and the Comfort Inn Stormwater Retention Pond. The two projects have coordinated resources to attempt to arrive at a determination as quickly and efficiently as possible. It appears that the TLC project is ahead of the latter, so therefore will pursue the determination from the Army Corps.

For the TLC, two options are envisioned for impacts to the ditches. The ditch on the west side of the CKC can either be:

- Piped under the south approach ramp for a length of less than 300 feet, or

- Can be rerouted into the east ditch prior to the start of the south approach ramp.

5 Project Studies

Multiple studies were performed prior to selecting the four final bridge alternatives, as shown in this TS&L report. These studies were used to obtain a greater understanding of the project site as well as help to narrow down the number of bridge alternatives to only four of the most feasible options. Each of the studies are described in more detail below.

5.1 Aesthetics/Public Opinion

The City is looking for a signature/iconic structure to connect the CKC trail at Totem Lake. COWI and VIA collaborated on over ten initial bridge structure types and layouts. Each bridge concept was developed considering project site constraints, and attempted to incorporate natural elements present at Totem Lake or within the CKC. Each bridge concept went through internal evaluation for structural feasibility, constructability and site aesthetics, and based on this criteria, the bridge alternatives were narrowed down to the five most feasible options.

At the second public open house, survey data was collected to gauge public interest in each of the five bridge alternatives. Open house attendees were asked to selected their first choice and second choices among the five alternatives listed. Data was also collected in the form of an online survey on the Totem Lake Connector website. Results from this survey data were used to further narrow the concepts down from five to four alternatives.

A final public tally was cast at the third and final public open house. At this open house, attendees were allowed to pick their first and second bridge choices from the four final alternatives.

Boards from each open house can be found in Appendix I.

5.2 Geotechnical

5.2.1 Foundations

From the investigation, deep foundations are expected for all bridge foundations. Due to the geology of the site, settlement is a primary concern for shallow foundations. Options for the considered foundations included:

- Aggregate piers
- H piles
- Pipe piles
- Auger cast piles (18" diameter)
- Drilled shafts

It is advisable to use one foundation type at all locations, and due to the need for lateral shear strength, and potential for liquefaction and lateral spreading, drilled shaft foundations were selected for the 10% designs.

As an option to provide lateral foundation resistance and/or uplift capacity, soil anchors are recommended for the Half Arch alternative.

5.2.2 Retained Earth Ramp

For the retained earth ramp at the south end of the bridge, settlement is still a key consideration. Therefore, a MSE wall with deformable facing is recommended. This could come in the form of a vegetated wall, terraced wall system, or wire faced MSE using gabion baskets with or without facing panels.

The pavement structure should be placed following the development of short-term settlement.

5.3 Level of Service (LOS)

COWI and MIG|SvR conducted an extensive study on Level of Service (LOS) capacity for various deck widths and recommended a final clear deck width of 14 ft for the Totem Lake Connector. No immediate delineations are recommended.

The following data/information was used to arrive at these conclusions:

- FHWA SUPLOS Model for evaluating Level of Service (LOS) – The FHWA model is focused on cyclist comfort only. This memo produces a case study of the new University of Washington pedestrian/cycling bridges to give a clearer understanding of the LOS terminology.

- FIB 32 Walkway Capacity - This European code based tool provides capacity for the bridge when used by dense pedestrian crowds (in which case cyclists will dismount and become a pedestrian).

- Matrices with reference bridges at various widths - Peak Hourly Volumes are reported for the various example bridges.

- 2016 Bike and Pedestrian Count Data - Data includes Seattle, Copenhagen, Vancouver, Calgary, and Ottawa. Actual and average Peak Hourly Volumes seen by the counters are compared to the predicted SUPLOS calculated capacities. Comparison against major urban bridges in the cities give an upper bound on the Peak Hourly Volume that could potentially be seen on the Totem Lake Connector in the future.

- Bridge Density (Calculation) - To understand how many people are on the bridge, we converted the SUPLOS volumes to density and relate that back to the FIB 32 density. SUPLOS results are between 0.6 and 1.2 users per 40-ft of bridge length under the peak capacity.

- Public Outreach - Completed public outreach via a public meeting to obtain input on desired widths, and 14-ft clear width was the highest scoring of widths ranging from 12-ft to 18-ft.

5.4 Urban Design Analysis

The purpose of this study was to explore urban design conditions and opportunities related to the Totem Lake Connector's southern landing. This location is in the heart of the future Totem Lake Village. The City envisions Totem Lake Village as transforming into a vibrant, pedestrian oriented mixed-use area (Kirkland Comprehensive Plan).

The primary purpose of the bridge is to serve the Cross Kirkland Corridor Trail. This trail allows pedestrians, cyclists, and other non-motorized transportation users to move from neighborhoods to other neighborhoods, retail centers, and employment centers with ease by providing a continuous connection across existing barriers to movement, such as topographical features and wide vehicular arteries.

The CKC trail will have a large influence on the character of Totem Lake Village. The City's vision for engaging with the trail states: "Ensure when [development] occurs adjacent to the Cross Kirkland Corridor that the building and site features integrate with the corridor to create active and engaging spaces for corridor users," (Kirkland Comprehensive Plan, Policy TL-10.1). Likewise, the trail's users, when engaged as an asset, will generate development opportunities along the trail.

The southern landing, which is the focus of this study, is envisioned to complement the Natural Center as a "Village Center". This node and access point, located at the heart of the future community, is an opportunity to create a vibrant plaza to anchor the district's open space system. Trail users along with residents and workers in the district will activate the space and create development opportunities around it. Ground oriented housing can be used to increase natural surveillance and safety of the public realm.

Based on this urban design study undertaken by VIA Architecture and direction from the City, it was concluded that the TLC should touch down as soon as possible, while retaining a grade below 5%.

5.5 Cost Estimate

Comparative cost estimates were generated for each of the four alternatives. Although the designs are at a 10% level, they are much more developed than in a typical preliminary engineering phase. This was necessary for developing accurate renderings, concept validation, and to devise accurate construction sequence/methods. This all helps to give a higher level of confidence to the quantities associated with these concept designs. Although these design alternatives have been developed more than typical for a preliminary engineering phase, the 10% design level carries inherent design uncertainty for each bridge alternative. The accuracy of an estimate for a 10-30% design is -30% and +50% according to the WSDOT Estimating Guidelines April 2015, Table 4-1: Cost Estimating Matrix, shown in Figure 4 below.

The following items are considered in the 10% cost estimate:

- No contaminated material removal and disposal is included.
- No property acquisition is anticipated and therefore is not included.
- Only minor wetland mitigation and basic landscaping costs are included.
- No roadway or modification of signals are anticipated as part of this project and therefore are not included.
- Utility conflicts have not been fully vetted at this stage, and therefore costs for relocation are approximate.
- Impacts to stormwater and drainage are anticipated to be minimal, and therefore costs are only included for small incidentals and a culvert for the south approach ramp.

Project Development Phase	Percentage of Design Completed	Purpose of Estimate	Methodology	Tools	Estimate Range
Planning Washington Transportation Plan Highway System Plan Design Studies Route Dev. Plans	0% to 2%	Screening or Feasibility WTP/HSP (20-Year Plan) WTP – Washington Transportation Plan HSP – Highway Systems Plan	Parametric	PLCE and/or MP3	-50% to +200%
	1% to 15%	Concept Study or Feasibility Implementation Plan (10 Yr. Plan)	Parametric Risk-Based	PLCE and/or MPE Risk assessment models	-40% to 100%
Scoping Project Summary (PD, DDS)	10% to 30%	Budget Authorization or Control Capital Improvement & Preservation Plan (CIPP)	Parametric Historical Bid-Based Risk-Based	PLCE and/or MP3 UBA, BidTabs Pro Risk assessment models	-30% to +50%
Design Design Documentation I/S Plans for Approval Design Approval	30% to 90%	Design Estimates (Project Control of Scope Schedule Budget)	Historical Bid-Based Cost-Based Risk-Based	UBA, BidTabs Pro Risk assessment models	-10% to +25%
PS&E Plans, Specs, Estimate (R/W Plans approved)	90% to 100%	Engineer's Estimate (prior to bid)	Historical Bid-Based Cost-Based Risk-Based	EBASE, UBA, BidTabs Pro, Risk assessment models	-5% to +10%

Figure 4: Cost Estimating Matrix, WSDOT Cost Estimating Manual Table 4-1

The cost estimates are developed based on an initial set of unit prices based on a multitude of sources for projects both locally as well as internationally. The base unit costs were developed primarily based on the following sources:

- WSDOT BDM, June 2016;

- WSDOT Highway Construction Cost Index, June 2016;
- Tukwila Pedestrian Bridge Bid Tabulation;
- Granite Falls Bridge No. 102 TS&L Cost Estimate; and
- Recent COWI Project Data (Ohio River Bridge, MacDonald Bridge and Columbia River Skywalk).

The above cost information was used to give each line item a unit cost. These unit costs were adjusted based on engineering judgement, transportation and fabrication costs, and current material/market prices. The unit price for base steel was left as variable, with basic fabrication and rolled sections priced as twice the cost of base steel. Steel requiring complicated fabrication was priced at the highest level.

The overall cost of the bridge will depend largely on the unit price of steel. As a way to compare each of the options and their dependence on this price, Table 1 shows the comparative cost of each option as a range of prices at two different base steel prices, $1.00 and $2.00 per pound. The table also shows each of the bridge costs as a percentage of the lowest cost option (the Gates) for this same range of steel prices. The Skipping Stone price stays within 1-2% of the Gates, while the Half Arches and Suspended Ring have varying relative price ranges. When the price of steel is low ($1.00/lb), the Half Arches and Suspended Ring prices are within 5% of each other, but when the price of steel is high ($2.00/lb) the price of the Suspended Ring is about 20% higher than the Half Arches.

	Option A: The Gates	Option B: Skipping Stone	Option C: Half Arches	Option D: Suspended Ring
Comparative Cost (Low & High Steel Price)	$12.0 - $13.8 M	$12.2 - $14.1 M	$14.7 - $16.4 M	$15.3 - $17.9 M
% of Lowest Cost Option	100%	102%	119% - 123%	128% - 130%

Table 1: Relative Cost of Bridge Option Based on Unit Price of Steel (Today's Dollars)

Another cost associated with each option, but not included in the cost estimate or evaluation criteria, is the design-engineering fee for each. Both the Skipping Stone and Half Arch options will have final design fee in the range of $800-$900K. The Gates and Suspended Ring options will carry higher design costs because each will require a wind tunnel study. In addition, it is recommended that the Suspended Ring option have an independent design review of the loop ramp section. These options will have final design fees in the range of $850K-$1M for the Gates (including wind study), and $900k-$1.1M for the Suspended Ring (including wind study and independent design check).

6 Structural Alternatives

Four (4) bridge options have been developed as part of this Type, Size and Location study. Each of the options are described in further detail below. The alignment and approach ramp/structures are the same for each alternative. Preliminary drawings for the alignment, approach ramps, and each alternative can be found in Appendix A.

6.1 Alignment and Profile

Following extensive studies of alternative alignments, a simple linear alignment with a single loop at the north ramp was determined to be the preferred alignment. Appendix M summarizes the range of alignment options studied during the preliminary design phase.

This selected alignment and profile is the same for each of the four bridge alternatives. The alignment shifts the centerline of the existing trail to the west side of the CKC right-of-way by approximately 25 ft and then rejoins the original trail alignment at the north end of the bridge following descent around the loop ramp. This alignment shift allows for piping the west ditch into a culvert for less than 300 ft, provides sufficient clearance from the future PSE power lines, avoids other utility impacts, accommodates the Sound Transit transportation easement, and allows for a secondary trail along the existing interim trail bed, which will accommodate future maintenance vehicles for utility companies.

The bridge profile has a maximum grade of 4.75% along the south approach and a maximum grade of -4.30% along the centerline of the loop ramp, which results in a grade along the inner curb face of less than 5.0%. The grade along the outer curb is even more gradual.

6.2 Bridge Approaches

6.2.1 South Approach

The approach ramp will be composed of retained fill, cuts, and fill slopes. An asphalt riding surface will be used to better accommodate any settlement without cracking. MSE walls (battered or vertical) will be provided along either side of the ramp where fill slopes cannot be used.

The approach ramp ends at an abutment wall and pile cap that will serve as the southern landing point for the bridge structure. It is estimated that the pile cap and abutment wall will be supported on two drilled shafts extending 50 ft deep.

There is a desire to provide attractive, natural landscaping along the secondary trail using native plants.

6.2.2 North Approach

The north approach ramp will act as a fixed link for the end of the loop ramp. This ramp will be made integral with a robust abutment comprised of a large pile cap supported on a set of drilled shafts. The drilled shafts are anticipated to reach a depth of 70 ft below the base of the pile cap.

6.3 Option A: The Gates

The Gates are comprised of a series of three V-shaped towers with stay cables supporting the bridge spans at their third points on each side of deck. This option utilizes symmetric spans with equal towers at each location.

6.3.1 Foundations and Substructure

The main piers (the Gates) consist of concrete pedestals with steel tower legs extending up on either side of the deck. The tower legs are trapezoidal in cross section, and tapered through the height of the leg. The stay cables are supported at the top of each tower leg, where the section is at its smallest.

The concrete pedestals resemble a bulging rectangular prism with a partial cylindrical cutout where the tower legs meet the pedestal. The pedestals are supported on a pile cap and a single drilled shaft on the order of 8 ft diameter. The shaft depths vary depending on soil conditions at each pier location.

The loop ramp substructure is composed of six steel 'Y' piers of varying height. Each of these piers sits on a trapezoidal concrete pedestal and is supported by a single small diameter drilled shaft. Though the column heights vary, the top of the Y-support uses constant geometry for a uniform look as the ramp gradually decreases in elevation. This also simplifies fabrication.

6.3.2 Superstructure

The superstructure for the Gates option is simple, yet effective. The deck system is composed of two edge girders, floor-beams and a concrete deck, along with cables supports at several locations. The bridge railing sits on top of each edge girders along the entire length of the bridge.

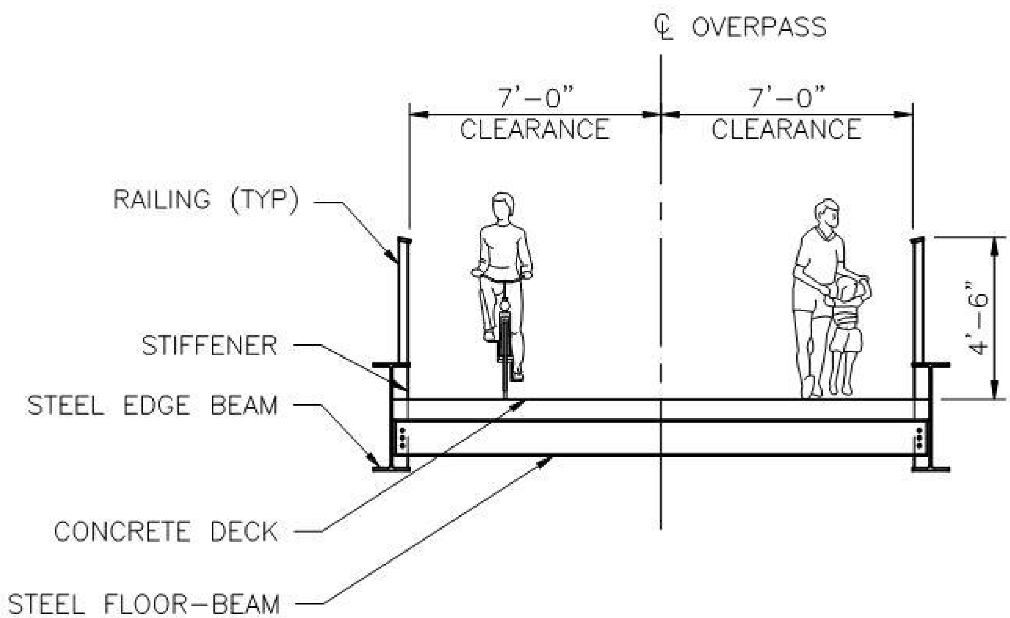

Figure 5: The Gates Deck Section

The concrete deck allows for a smooth and continuous wearing surface for users. This type of wearing surface is ideal for cyclists, provides high grip for easy maneuverability and changes in speed, and is low maintenance.

6.3.3 Constructability

The Gates alternative can be constructed using the balanced cantilever method. In this method, the superstructure is built out equally on either side of the tower, as to balance the deck on one side with the other. The continuous edge beams are erected from the tower to just past the stay cable with floor-beams in place and without the concrete deck. Once this erection has been completed for each tower and set of cables, the middle sections of each span will be 'dropped-in' and spliced to the existing edge beams using a simple shear splice. These 'drop-in' spans can be set by a crane using a single nighttime road closure for each.

Construction of the loop ramp will be completed by first erecting the loop ramp 'Y' supports. Then sections of the superstructure can be built on the ground and a crane used to place each section onto previously erected support piers.

The deck design is easily constructible, as it is a combination of partial depth precast panels and cast-in-place (CIP) concrete composite overlay. The precast deck panels are placed between floor-beams and will be set as steel superstructure elements are erected. The CIP concrete acts as infill between panels and makes the floor-beams composite with the deck. The overlay provides a smooth finished deck.

6.3.4 Vibration Analysis

As described in Section 5 of the Basis of Design document (see Appendix C), vibration analysis is performed based on the SETRA method. SETRA specifies four frequency range classifications that are based on risk of resonance for both vertical and horizontal directions. Preliminary vibration analysis was performed for each of the four bridge options to determine if any will require damping.

According to preliminary analysis, the Gates may require damping on the two center spans passing over NE 124th St and Totem Lake Blvd. Tuned Mass Dampers were conservatively assumed as 3% of the modal superstructure weight for the spans requiring dampers. The dampers could be attached to the underside of the concrete deck in-between floor-beams, making them nearly invisible from traffic below. This type of damper would be similar to the type used on the Millennium Bridge in London.

6.4 Option B: Skipping Stone

This bridge has a strong fluid form that engages the connection between Lake Washington and Totem Lake. The sense of motion of a skipping stone implies a reconnection between the community and nature.

The Skipping Stone option is comprised of several undulating arches that span below and above the deck as the bridge crosses the roadways. The arches are splayed outward where they rise above the deck surface to provide an open, uplifting experience for users.

6.4.1 Foundations and Substructure

The main bridge spans are supported on post-tensioned concrete 'Y' piers that each sit on a single drilled shaft. The concrete 'Y' piers are post-tensioned between the tops of the Y legs against a steel pipe strut to avoid deflection of the legs under superstructure dead load. The drilled shaft foundations are envisioned to utilize collars as a way to transition between the main pier and the drilled shaft below, which can be very economical.

Similar to the Gates substructure, the loop ramp is also supported on steel 'Y' piers. These piers also sit on a trapezoidal concrete pedestal that frames into a single drilled shaft below. Unlike the Gates loop ramp, the Skipping Stone ramp sits on five steel piers and one concrete pier.

6.4.2 Superstructure

The Skipping Stone superstructure uses a similar system to the Gates. The deck system is composed of steel pipe arches, steel pipe tie-chords, pipe hangers/struts, transverse floor-beams, and a concrete deck. This option uses a combination of partial depth precast panels with a composite CIP concrete overlay for the final deck configuration. Precast panels are placed on the spans between floor-beams, then CIP concrete is applied to make the concrete composite with the floor-beams and create a uniform final riding surface. Concrete curbs on each side of the deck provide mounting area for the railing.

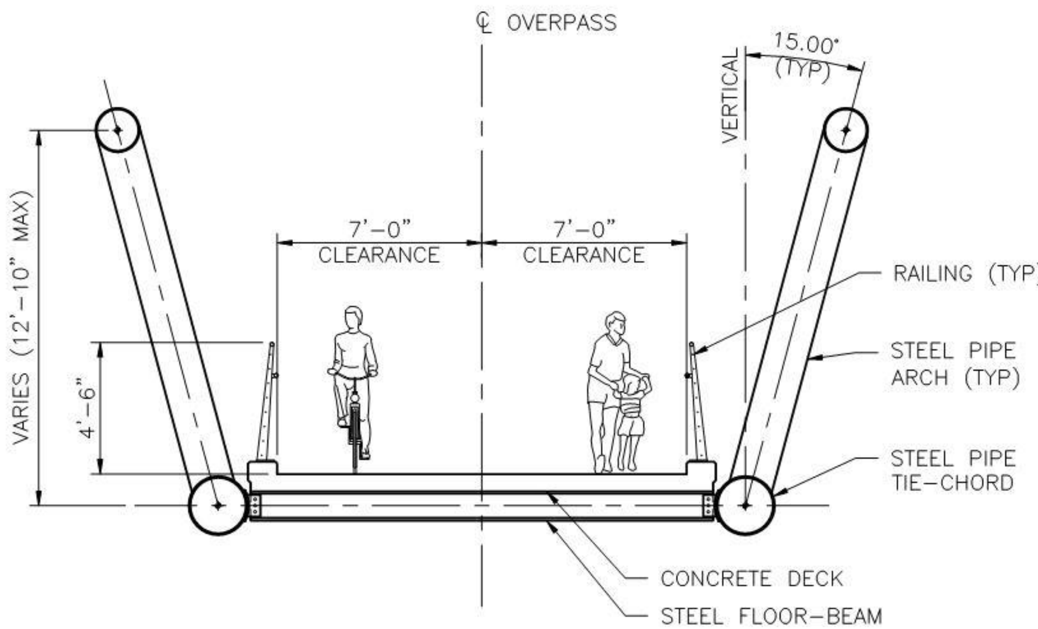

Figure 6: Skipping Stone Deck Section

The loop ramp portion of the bridge uses the same deck system, but does not include the steel arches. The steel pipe tie-chords continue through the loop ramp acting as edge-beams that span between Y-piers.

6.4.3 Constructability

Construction of the Skipping Stone option is straightforward. Each of the arched spans will be assembled on the ground in a staging area adjacent to the site, and then moved into position with a truck and bogie for lifting using a tandem crane pick. For the longest span, the assembly will likely need to occur in the space on the south side of NE 124th St. This implies that the bridge superstructure will have to be assembled and erected before the south abutment is constructed to provide adequate space for assembly of the spans. The traffic island could be used as a laydown area for the duration of the project to assemble the shorter spans. We also identified an area of the adjacent 24 Hour Fitness parking lot that could potentially be rented by the Contractor as a site office and material stockpiling area.

Though the Skipping Stone uses a simple deck system, the arch spans will require a certain amount of fabrication. Each of the hangers/struts needs to be cut to length and welded to the pipe arch on one side and the pipe tie-chord on the other.

6.4.4 Vibration Analysis

It is unlikely that the Skipping Stone option would require supplemental damping due to the sufficient stiffness provided by the arch system.

6.5 Option C: Half Arches

Two "half-arch" spans step down toward the lake, providing a landmark form and expressive gesture of motion toward Totem Lake. Paired vertical elements create a series of portals that create an interesting experience for users moving across the bridge.

The Half Arches are an innovative hybrid of a typical tied-arch bridge system and a cable stayed system. The steel towers support a harped cable configuration that directs load into the curved towers as compression with limited bending. The stay cables support the deck at an equal increment of 10 ft along the span. The tip of the tower is anchored using a set of backstay cables that create equilibrium in the system. In an arch, each half resists the other at the crown; in the case of the Half Arch system, this compression is replaced by tension held in these backstays. The stays put the deck into compression, which is resolved by the backstays.

6.5.1 Foundations and Substructure

Each of the steel tower legs is supported on a concrete pedestal rising from a pile cap on a pair of drilled shafts. The backstay cables frame into a 'tie-down' pier that is a tapered trapezoidal concrete section. A post-tensioned tendon loops through each tie-down pier to transfer the tension forces from the cable into the pier. Each pier sits on a large pile cap and set of two drilled shafts. Because the tie-down piers are tension-resisting elements, there are also six soil anchors splayed from the pile cap into the ground. The soil anchors utilize the weight of the soil cones through their bonded length to resist the tension demands.

The loop ramp is supported on six simple circular concrete columns supported concentrically on a single drilled shaft.

6.5.2 Superstructure

The superstructure for the Half Arches is envisioned to use full-depth precast panels for the main spans and cast-in-place construction for the back spans and loop ramp. The deck sections for the Half Arches are shown below in Figure 7 and Figure 8. Figure 7 shows the cable-supported deck sections, which will have embedded cable anchors and are lighter sections.

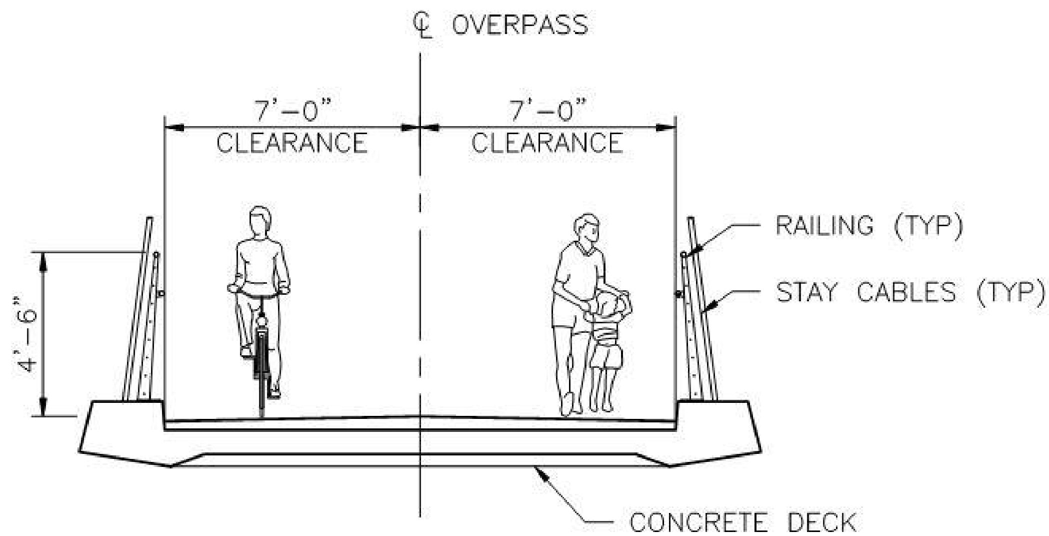

Figure 7: Half Arch Deck Section

Figure 8 shows the deck section between the arched towers and the tie-down piers, as well as for the entire loop ramp. This section has additional depth to resist higher bending in those spans. This configuration also allows for a uniform look throughout the loop ramp and is integral with the concrete support columns.

6.5.3 Constructability

The most complicated part of constructing the Half Arches will be the erection of the main span arched tower legs and the cable supported deck spans. The steel tower legs will be assembled horizontally on the ground at the site and lifted into position with the cables already attached. Once the towers are erected and the backstay cables secured, the cable supported deck panels can be installed one panel at a time using cantilevered construction. The pipe of the Half Arch towers will consider this temporary imbalanced construction loading as a prime design check. This case imparts bending in the tower until the span is completed.

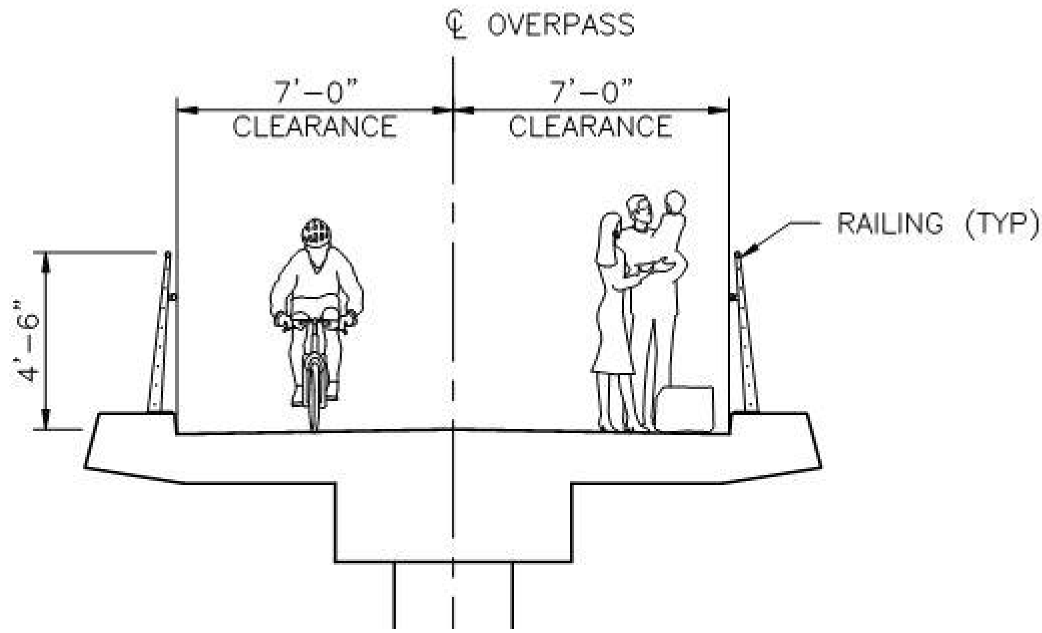

Figure 8: Half Arch Deck Section – Loop Ramp

The cast-in-place concrete loop ramp will be constructed using plywood forms built on site. Each of the drilled shafts and columns will be constructed first, then temporary supports and formwork can be constructed to form the loop ramp deck section.

6.5.4 Vibration Analysis

The Half Arches may require some damping due to an excitable first vertical mode. However, further analysis will need to be performed to determine exactly what type and extent of damping is needed. The concrete deck sections for this bridge option provide more superstructure mass than other options, and is therefore harder to excite.

6.6 Option D: Suspended Ring

The Suspended Ring places the main structural feature at the edge of Totem Lake Park and creates a visual way-finding element for the new corridor and park area. Special "water droplet" portals are created within the cone of cables supporting the apparently hovering loop ramp structure, which uses a single, raked pylon. This is achieved by using the concepts of a curved ring girder to resolve torsion in the deck. The cables are supported from vertical outriggers, which allow the tension force to pass through the centroid of the deck so torsion demands are minimized.

The Suspended Ring option uses an eccentric truss to span the roadways, with an undulating top chord. Having the main spans framed on only one side of the deck by the inclined truss, user view of the cable supported loop ramp is unimpeded and becomes a visual attraction.

6.6.1 Foundations and Substructure

The main bridge sits on five trapezoidal concrete piers, each supported by a single drilled shaft foundation. It is envisioned that each drilled shaft will utilize a collar at the top to provide adequate area to transition between the pier and drilled shaft below.

There is only one foundation located within the loop ramp for the Suspended Ring option. The single mast that serves as the support for the loop ramp cables sits on a conical concrete pedestal rising from a drilled shaft. The mast itself is formed of steel pipe and is tapered at the base and the top. The mast sits on a simple pot bearing on the pedestal to allow the loop ramp structure to move slightly under different loading conditions. By allowing this type of movement, the mast will not be subjected to large bending forces at the base.

6.6.2 Superstructure

The Suspended Ring superstructure is composed of a steel torsion box girder, with cantilevered deck from one side. This deck section will have transverse steel diaphragms at approximately every 6 ft with longitudinal stiffeners running the length of the top plates. Vertical outriggers in the loop ramp are spaced at approximately 12 ft. This spacing is consistent with the truss spans, where the vertical elements also help to provide buckling restraint to the top chord.

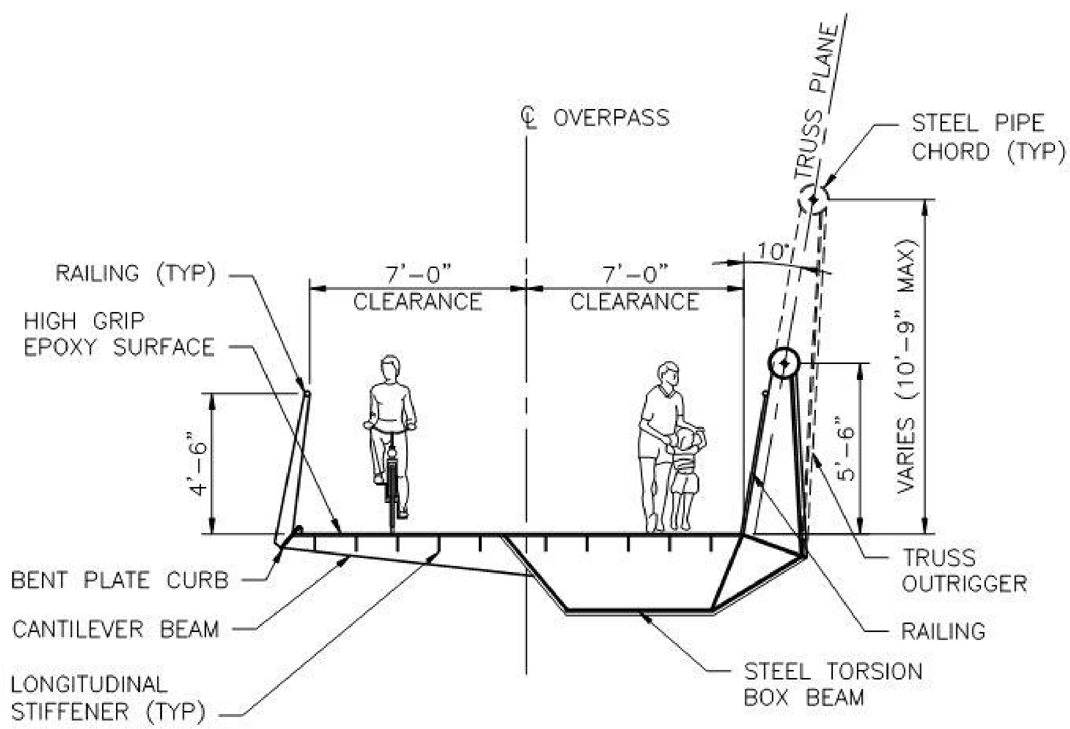

Figure 9: Suspended Ring Deck Section

The steel box will use a steel orthotropic deck covered with a high grip epoxy wearing surface for the length of the main bridge and loop ramp.

6.6.3 Constructability

The two biggest construction considerations for the Suspended Ring are fabrication and erection of the loop ramp. The steel box girder will require a higher level of fabrication than any of the other options due to the geometric complexity of the section as well as a number of stiffeners and plates that need to be added to build up the final section. The preliminary section is conceived using simpler fillet welds where possible.

For the erection of the loop ramp, it is thought that portions of the span be erected on temporary towers. Then then central section could be lifted and held into position using temporary stays anchored from the spire of the central mast.

6.6.4 Vibration Analysis

The Suspended Ring will likely require vertical and horizontal damping in the loop ramp section of the bridge. The dampers can be installed inside the steel box girder, with access hatches in the deck level to facilitate installation and maintenance.

7 Alternative Evaluation

A set of criteria were developed to evaluate and compare each of the bridge alternatives based on public input, cost, engineering, construction, and other considerations.

7.1 Evaluation Criteria

The following table shows the criteria and weighting used to evaluate each of the options. The goal of scoring each of the options is to arrive at the bridge alternative with the highest overall score. The criteria and scoring are described in further detail below.

Criteria	Weight
Public Preference	**20%**
Project Costs	**35%**
Total Initial Cost	*25%*
Lower Material Escalation Risk	*5%*
Perceived Construction Risk	*5%*
Environmental Impacts	**5%**
Geotechnical	**10%**
Structural	**10%**
Seismic Performance	*5%*
Pedestrian Induced Vibrations	*5%*
Constructability	**10%**
Constructability	*5%*
Fabrication	*5%*
Operations & Maintenance	**10%**
Low Total Maintenance Cost	*5%*
Ease of Inspection/Maintenance	*5%*
TOTAL =	**100%**

Table 2: Evaluation Criteria

In addition to the criteria listed in the table above, several other categories were initially considered. However, these additional criteria were deemed essentially the same for each of the bridge options, so were not included in the final scoring. Some of these additional considerations include:

- Connectivity,
- Functionality,
- Construction impacts to business/residential/recreational facilities,
- Aesthetics,
- Bridge profile,
- ROW impacts,
- Hydraulics/drainage,
- Hazardous materials,
- Emergency access,
- Snow removal,
- Public safety, and
- Traffic impacts.

7.1.1 Public Preference

Public Preference carries 20% of the overall score. Scores for public preference are purely based on survey data collected online one week before, as well as at Open House #3 held on May 4, 2017. Participants were asked to select their first and second choices of bridge options. Votes for first choice were given a weighting score of 2 points, and votes for second place were given a weighting score of 1 point. Each option earns points as:

- 20% x (Votes for Given Option) / (Most Votes for an Option)

7.1.2 Project Costs

Project costs hold the highest weighting and makes up 35% of the overall project score. This criteria has several subcategories including total initial cost, lower material escalation risk, and perceived construction risk. Total initial cost is worth 25% of the overall score, while lower material escalation risk and perceived construction risk are each worth 5% of the overall score.

The lower material escalation risk subcategory attempts to capture risk associated with variations in the price of steel and potential price escalation over time. The unit price of steel has been on the rise over the past few years and could continue to rise before the Totem Lake Connector is constructed. The initial cost of construction, calculated for each of the four bridge options, could change dramatically in the next few years depending on the price of steel. Therefore, options that are mostly built from steel will be largely dependent on the price. For this reason, the Suspended Ring received the lowest score due to the use of a steel box girder deck system. The Gates and Skipping Stone received middle scores for moderate use of rolled steel sections. The Half Arches use relatively little steel due to the use of a concrete deck system and received the highest score for this category.

In comparing the perceived construction risk of each of the bridge options, the Half Arches and the Suspended Ring score the lowest. This is due to the complexity associated with erecting either of these options, and a contractor may assign higher prices to these bridges. The Skipping Stone has lower risk than the Half Arches or the Suspended Ring, but the Gates has the lowest risk for construction due to a straightforward erection scheme and easily maneuverable components.

7.1.3 Environmental Impacts

Environmental Impacts make up 5% of the overall project score. This criterion considers temporary and/or permanent impacts to the wetlands and buffer zone and any other permitting concerns. Potential issues associated with the ditches on the south side of the bridge alignment are deemed to be the same for each option, and thus do not influence the comparative scores.

The Gates, Skipping Stone, and Half Arches each require two permanent piers to be placed within the wetland boundary; all other piers will remain outside of this boundary. For this reason, these options were each given a median level score and the Suspended Ring was given the highest possible score. Because the support structures for the Suspended Ring remain entirely outside of the wetland boundary, this option received the highest possible score for environmental impacts.

7.1.4 Geotechnical

Geotechnical considerations make up 10% of the overall score. The primary geotechnical risk associated with the Totem Lake Connector is unknown soil conditions at each pier location. Scoring for each of the bridge options was based on the number and function of the drilled shafts. For example, the lowest score was assigned to the Half Arch option because several of the tie-down piers will need to carry large tension forces. The preliminary design relies on soil anchors as well as drilled shafts to resist this uplift force, however, we do not have detailed soil data at those specific locations and cannot fully understand the uplift resistance the soil will provide.

The Gates and Skipping Stone options have more pier locations than the Suspended Ring, and therefore slightly more geotechnical uncertainty. The Suspended Ring was scores highest due to having only a single shaft in the loop ramp area. Comparatively, this option has much lower associated geotechnical risk than any of the other options with 5-6 piers in the loop ramp area.

7.1.5 Structural

Structural considerations also make up 10% of the overall score and consider both seismic performance and pedestrian induced vibrations. The seismic performance scores are based on how the structure will react under seismic loads. The scores for this subcategory are largely based on options that have locked in tension elements, like the Half Arches tie-down piers and the Gates that have tie-downs at the south abutment location.

The scores for pedestrian induced vibrations are based on preliminary analysis done for each of the bridge options. This analysis has shown that certain alternatives will likely require the use of dampers to counteract any live load excitation. The Gates and Suspended Ring options were given lower scores for this reason. The Half Arches may require some damping, but will not require as much as either the Gates or the Suspended Ring. The Skipping Stone is not anticipated to require any damping and is stiff enough to prevent any pedestrian induced vibrations.

7.1.6 Constructability

Constructability makes up 10% of the total project score. This category includes initial constructability of each option as well as ease of fabrication; each of these subcategories is worth 5% of the total score. Fabrication for the Suspended Ring will be the most complicated and time consuming of the four options, as it is the only option that uses an entirely steel superstructure. The Gates and Half Arches are the least complicated to fabricate because they use mostly typical rolled steel sections and will not require major modifications or connections. The Skipping Stone steel arches will require an extra level of fabrication, but still uses typical standard steel sections.

Constructability varies for each of the four bridge options. The Half Arches and the Suspended Ring will likely be the most difficult to build and therefore receive lower scores. It will ultimately be the contractor's responsibility to conceive an appropriate erection plan, but these two options will require higher-level erection planning than either the Gates or the Skipping Stone. The Skipping Stone bridge will require a large laydown area in which to assemble the arch spans, as well as a large crane to pick and set each span, and was therefore given a slightly lower score than the Gates.

7.1.7 Operations & Maintenance

Operations and Maintenance account for 10% of the overall project score, with low total maintenance cost and ease of inspection and maintenance each worth 5% of the total score. The total maintenance cost is closely tied to the amount steel on each bridge that would require painting over time. This score also considers maintaining/replacing cables, maintaining or adjusting dampers, and wearing surface maintenance.

The Suspended Ring receives the lowest score for this category due to the large amount of painted steel on the bridge, as well as the cost of maintaining dampers and the epoxy wearing surface on the deck. The Gates and Skipping Stone receive a better score due to the smaller amount of steel on these bridges, and the concrete decks for these options requires little to no maintenance. The Half Arches receive the highest score because it uses an entirely concrete deck system that requires very little maintenance, with some painting required for the steel towers and possible cable replacement in the future.

The ease of inspection and maintenance subcategory is meant to measure the level of equipment and effort necessary to maintain and inspect the bridge. The Skipping Stone option is the most accessible because the towers do not extend very high off the ground and can be reached with a simple scissor lift. All other options would require a boom lift to access the taller towers and cable connections. The Gates received a slightly higher score than other cable-supported options because the towers are not quite as high, and there are fewer cable connections that will require inspection.

7.2 Evaluation Comparison

The final scores for each bridge option are shown in Table 3 below.

		OPTION			
Criteria	**Weight**	**A Gates**	**B Skipping Stone**	**C Half Arches**	**D Suspended Ring**
Public Preference	**20%**	**10%**	**20%**	**11%**	**13%**
Project Costs	**35%**	**33%**	**32%**	**28%**	**23%**
Total Initial Cost	*25%*	*25%*	*25%*	*21%*	*20%*
Lower Material Escalation Risk	*5%*	*3%*	*3%*	*5%*	*1%*
Perceived Construction Risk	*5%*	*5%*	*4%*	*2%*	*2%*
Environmental Impacts	**5%**	**3%**	**3%**	**3%**	**5%**
Geotechnical	**10%**	**8%**	**8%**	**6%**	**10%**
Structural	**10%**	**6%**	**10%**	**6%**	**8%**
Seismic Performance	*5%*	*3%*	*5%*	*2%*	*5%*
Pedestrian Induced Vibrations	*5%*	*3%*	*5%*	*4%*	*3%*

Constructability	**10%**	**10%**	**8%**	**7%**	**4%**
Constructability	*5%*	*5%*	*4%*	*3%*	*3%*
Fabrication	*5%*	*5%*	*4%*	*4%*	*1%*

Operations & Maintenance	**10%**	**8%**	**9%**	**8%**	**4%**
Low Total Maintenance Cost	*5%*	*4%*	*4%*	*5%*	*1%*
Ease of Inspection/Maintenance	*5%*	*4%*	*5%*	*3%*	*3%*

TOTAL =	**100%**	**78%**	**90%**	**69%**	**66%**

Table 3: Totem Lake Connector Evaluation Criteria Scoring

8 Recommendation and Conclusions

The project evaluation criteria were developed considering all of the project goals, objectives, and constraints, including all site data currently available. This comprehensive list of criteria provided an unbiased scoring mechanism that was ultimately used to compare each of the four bridge alternatives. After scoring each of the options using the final evaluation criteria, the clear winner is the Skipping Stone.

As a way to examine the scoring results more closely, Figure 10 shows a graphical representation of the scores for each option. The bar graph shows a vertical bar for each alternative, made up of the public preference score (shown in dark blue) and a combination of all remaining evaluation categories (shown in lighter blue). This graphic shows how the public preference score effects the overall score for each bridge option. Only looking at the light blue bars (all scores except public preference), the Skipping Stone still has the highest score

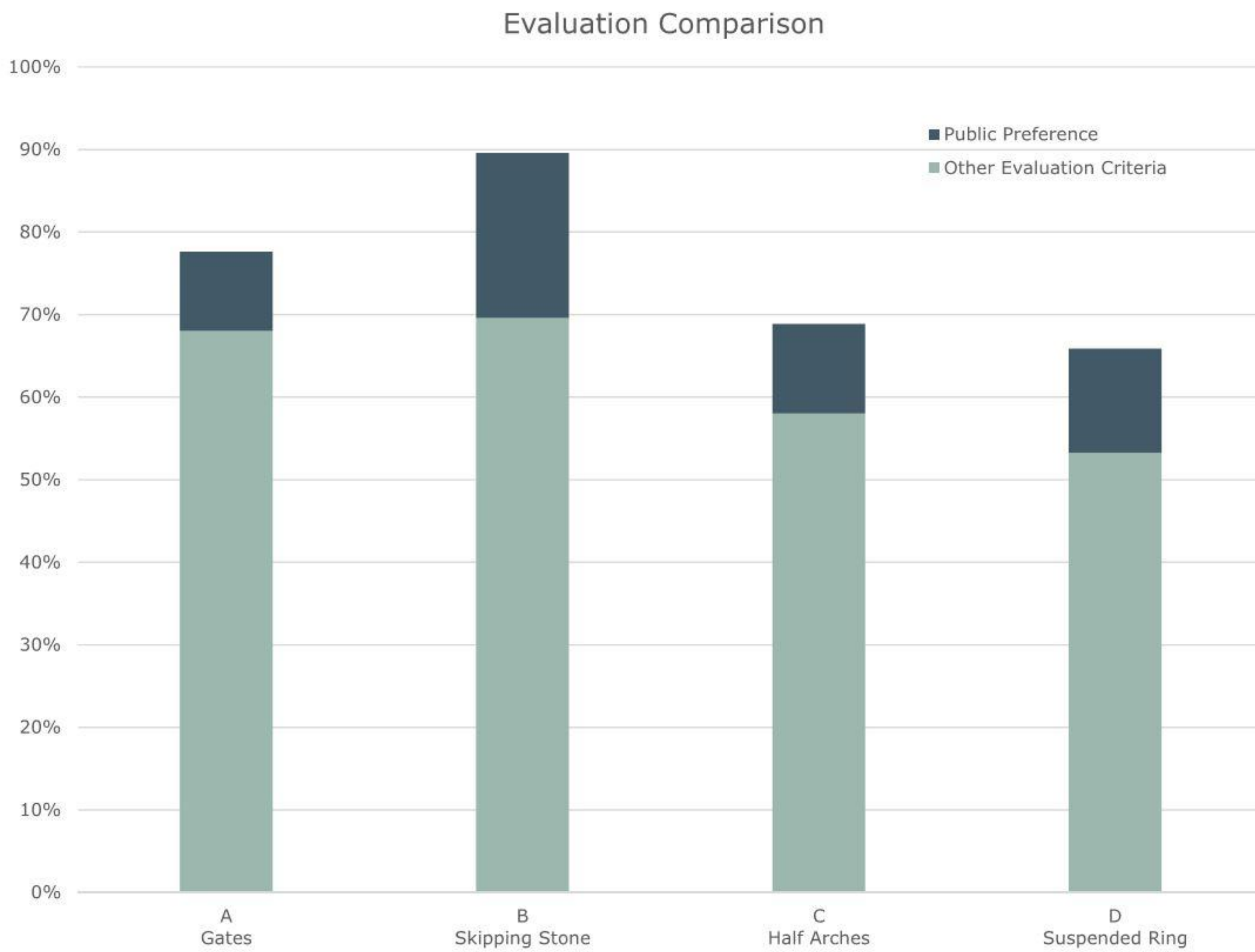

Figure 10: Alternative Evaluation Comparison

Based on the final scores for the evaluation criteria, COWI recommends proceeding to 30% design with the Skipping Stone option.